THE PA BIBLE

ADDITION NUMBER TEN
A CENTRAL CLUSTER SYSTEM FOR ROCK AND ROLL

The Music Box is an old movie theatre converted into a nightclub featuring a broad spectrum of high-energy live music (Figure 1). The club owner wanted a permanent sound system so good that word-of-mouth would squelch any rumors that groups were "being stuck with a house system", and he asked Electro-Voice to help design and install such a system. The conventional design for such an installation would be a split stack.

FIGURE 1 – The Music Box

Split Stacks

Traditionally, musicians pile speakers on both sides of the stage. Such split stacks can be seen everywhere, from large rock concerts to local musicians in small clubs.

Tradition aside, there are good reasons for using split stacks. Portability is a primary reason. Most road-worthy bass enclosures and high-frequency horns are stackable without special rigging; and, the position to the side of the stage area permits a lower height and simpler rigging. Using two systems allows for stereo operation and a better sound level distribution is produced than with one system on one side of the stage. If maximum sound power is limited, having systems close to the listening area produces at least one area of high sound pressure. Also, in some situations (such as L-shaped rooms) different sound pressure levels are desired in split systems.

There are problems with such a split system, however. With the speakers close to the listening area the sound pressure levels will be high close to the speakers but lower away from the speakers. Reverberation content at the back of the listening area will be high, while listeners close to the speakers will be in the near field. Listening positions at different distances from the two systems will suffer from interference effects due to phase cancellation between the two systems. In deep rooms the relatively low position of the stack makes separate coverage at the rear of the room difficult.

In contrast to the split stack, fixed installations, especially the deeper rooms, traditionally use a single "point source", or "central cluster" placed above the stage.

Single Cluster

The long narrow, reverberant room that resulted from the old theatre conversion suggested to us that such a system using a single cluster would function better than the conventional (for rock and roll) split system. The proscenium arch over the theatre stage would provide a good location for the central cluster, and the stage floor overhang would provide a location for the sub-woofers.

Two features of the Music Box, the dance floor in front of the stage and the balcony located at the back of the theatre, work against using a conventional split system. Such a system would create very high sound levels on the dance floor but much lower level, highly reverberant sound levels at the balcony. A single sound source from an elevated cluster permits separate coverage of theatre areas using constant directivity horns while eliminating the interference effects of multiple sound sources.

With the concept of a single cluster using constant directivity horns as a basis, we proceeded to design a three-way system using separate constant directivity horns for three separate theatre areas.

The Equipment

The block diagram, Figure 2, shows the system's components consisting of a sub- woofer section comprised of two folded

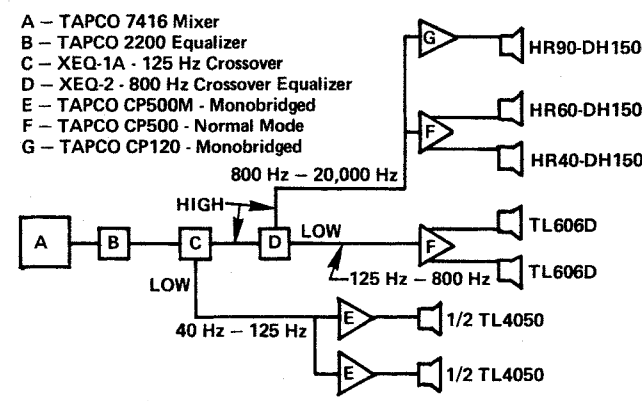

FIGURE 2 – Music Box Block Diagram

Qty	Model	Description
3	E-V DH1506	High-frequency driver
1	E-V HR90	90° x 40° short-throw high-frequency horn
1	E-V HR60	60° x 40° mid-throw high-frequency horn
1	E-V HR40	40° x 20° long-throw high-frequency horn
2	E-V TL606D	Mid-bass speaker system (optimally vented, including two 15-inch EVM15L Series II woofers)
2	E-V TL2025 (custom built)	Sub-woofer (horn loaded; equipped with one EVM15L Series II)
1	E-V XEQ-2	Electronic crossover, with X800 800-Hz crossover-frequency module and EQA horn-equalization module
1	E-V XEQ-1A	Electronic crossover with 125-B3 125-Hz crossover-frequency module
1	E-V/TAPCO 2200	Octave-band two-channel equalizer
4	E-V/TAPCO CP500	Stereo power amplifier (255 watts per channel into 4 ohms, average sine wave power)
1	E-V/TAPCO CP120	Stereo power amplifier (61 watts per channel into 4 ohms, average sine wave power)
1	E-V/TAPCO 7416	16 in, 4-out mixing console

FIGURE 3 – Equipment List

horn speakers using 15-inch drivers, a mid-bass section consisting of two vented systems, each with two 15-inch speakers; and three high-frequency constant directivity horns, one for each of three separate areas of the theatre.

A list of the equipment used in the setup is shown in Figure 3. All system components are stock E-V and E-V/TAPCO products, with the exception of the custom-built TL2025 sub-woofers. The TL2025 is half of a TL4050, a folded horn scaled up from the Sentry IVB low-frequency section to accommodate two 15-inch EVM15L Series II woofers instead of the two 12-inch woofers. The TL4050 can provide solid bass down to 40 Hz and a maximum acoustic output of 84 (!) watts. That is over 100 times that of a typical "high output studio monitor speaker system". On its side each TL2025 slips easily under the stage. One of the TL2025 sub-woofers is shown in Figure 4. (Plans for the TL4050 are available by writing to Electro-Voice, Inc., 600 Cecil Street, P.O. Box 186, Buchanan, Michigan 49107.) The cluster which handles the range above 125 Hz is shown in Figure 5.

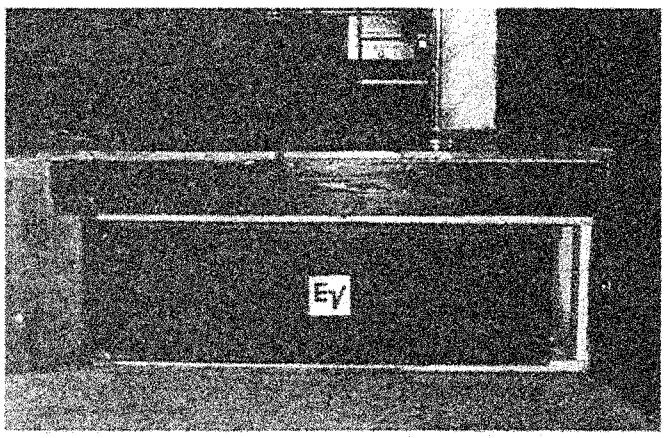

FIGURE 4 – TL2025

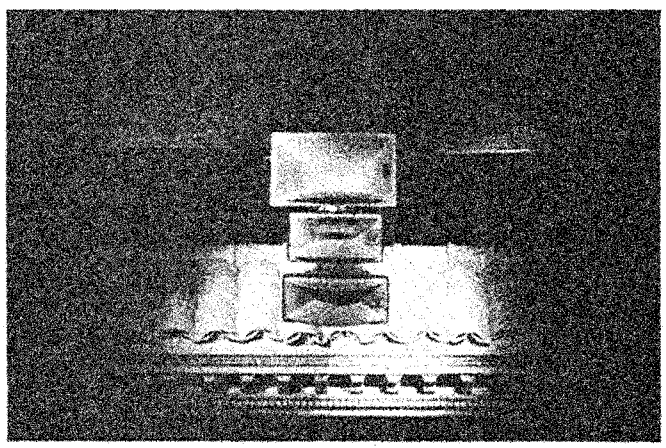

FIGURE 5 – Central Cluster

System Adjustment

The first step in adjusting the system was to correctly aim the high frequency horns to get uniform coverage over the floor and balcony areas. Horns were aimed as shown in Figures 6 and 7. Note that only one horn covered each audience area in order to virtually eliminate the interference effects. Such a design demands constant directivity horns, like the E-V HR series, whose coverage angles are essentially constant over the entire operating range.

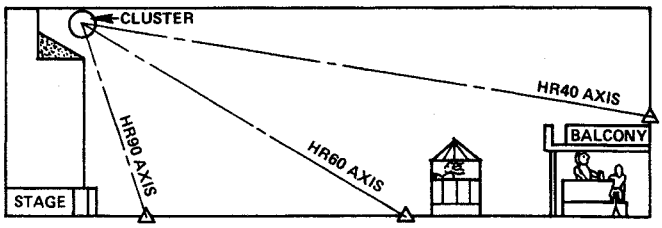

FIGURE 6 – Vertical Positioning

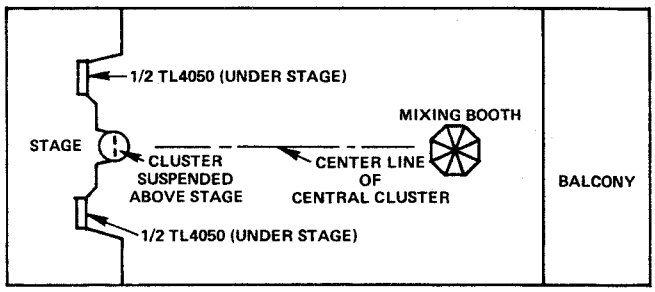

FIGURE 7 – Horizontal Positioning

From a practical viewpoint, the horns can be aimed visually, using the major conical (flat) portions of the horns as a guide. This is an important concept. The conical sections define the horn's 6-dB-down coverage angle. See Figure 8. For example, the angle between the HR90 and the HR60 was adjusted by viewing the cluster while walking backwards from a point within the HR90's coverage angle to a point within the HR60's coverage angle. The angle between the horns was set so the "top" conical section of the short-throw HR90 was leaving the viewer's line of sight as the "bottom" conical section of the mid-throw HR60 was coming into view. This resulted in a vertical angle of 40° between the horns with the horns' 6-dB-down vertical coverage angles approximately tangent. When all horns were aimed in this fashion, interference between any two horns was minimized and very uniform coverage achieved.

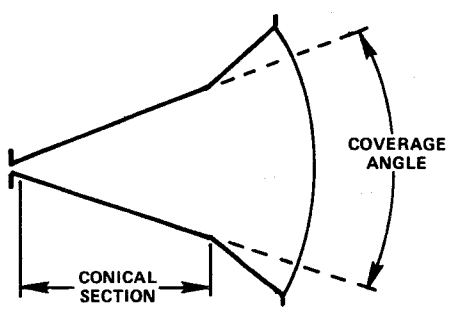

FIGURE 8 – Conical Section of Horn

As the block diagram shows, the system is tri-amped and the first step in adjusting the overall level and balance of the system was to adjust the relative levels of the horns, mid-bass, and sub-woofers.

While it was tempting to do this by ear using our favorite cassette featuring the Amazing Rhythm Aces (a popular way to EQ and adjust a rock-and-roll sound system) we decided to use the instrumentation employed by the professional sound reinforcement contractor. Specifically, we used an Ivie-30A real-time spectrum analyzer. The Ivie was driven with the output of three omnidirectional condenser microphones (custom manufactured at Electro-Voice). In this way, it was easy to assess the overall uniformity within,

say, the rated beamwidth of a given horn, without "walking the house" to get a feel for the average. The output of the three mikes was summed by a White Instruments Micplexer. This device averages the amplitude of each mike's output, so that the average sound pressure level – without regard to the relative phase of each mike's output – can be measured. (Simply running the three mikes into a mixer and using that output would give misleading results. For example, if two microphones were located in the room in such a way that the sound pressure levels at their diaphragms were of equal amplitude but exactly out-of-phase, the output of the mixer would be zero. In contrast, there would be plenty of output indicated by the Micplexer, since it sums only the amplitude of the signals.)

To facilitate system evaluation and adjustment, the output of the IE-30A was interfaced to a Hewlett-Packard 7035B X-Y recorder via an Ivie IE-17A. This combination of equipment made it super-easy to run hard-copy frequency response curves with a resolution of .2 dB.

Since there are three high-frequency horns, three separate level adjustments were required. These adjustments were:

1. With the HR60 and HR40 horns turned off, and with the measuring microphones in the HR90 coverage area, the relative levels of the HR90, mid-bass and sub-woofer were set. The system was then equalized using the octave band equalizer.
2. The measuring microphones were moved to the HR60 coverage area; and, with system on and balanced as in step 1, the HR60 horn was added to achieve a balance for the HR60 coverage area. The HR40 remained off during steps 1 and 2.
3. The measuring microphones were moved to the HR40 coverage area and the HR40 level adjusted to achieve a balance in the third area.

Step 1

Starting with the HR90 horn, we placed the three microphones well within the coverage angle of the short-throw HR90 horn. First, we turned on the mid-bass system (125 to 800 Hz), taking care that ambient room noise was at least 10 dB below the measured signal so that our readings would not be affected. The resulting mid-bass-only curve is shown in Figure 9. Second, we turned off the mid-bass systems and turned up the level of the short-throw HR90 horn so that its output matched that of the mid-bass systems. See Figure 10. Then, the mid-bass speakers were turned on again. The composite curve is shown in Figure 11. The SEQ-2 crossover has a polarity-reversal switch as well as an unusual control which can delay its low-frequency output by up to about two milliseconds at crossover. We made certain that the settings of these controls were consistent with the smoothest response in the crossover region. Finally, the sub-woofers were added to the system. See Figure 12. The overall system response is quite smooth, typical in smoothness of responses found in high-quality fixed installations after the "house curve" has been equalized with a multi-band, one-third-octave equalizer. The curve closely follows the Boner preference curve to 10,000 Hz. There is some experience and evidence – beyond the scope of this article – which indicates that clusters made up of constant directivity horns "sound best" when the 3-dB-per-octave rolloff of the Boner preference curve is somewhat less. Thus, we opted to boost the response in the highest octave using the octave band equalizer. The resulting curve is shown in Figure 13.

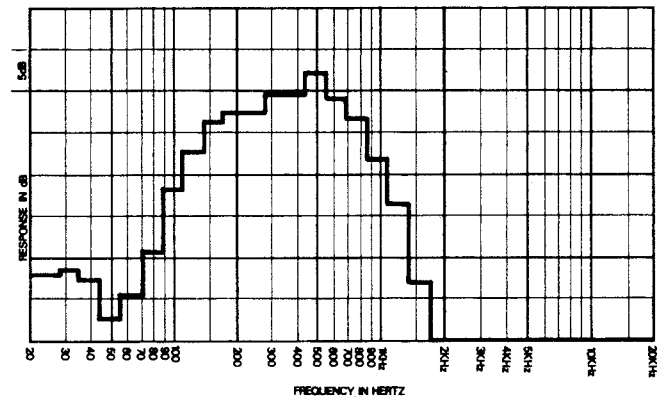

FIGURE 9 – Mid Bass Curve (HR90 Coverage Area)

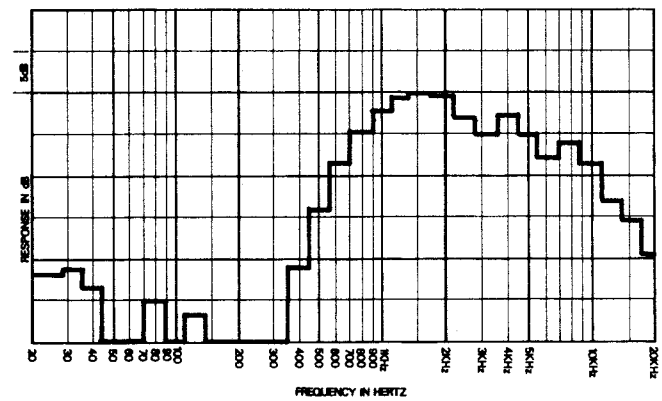

FIGURE 10 – HR90 Horn Curve

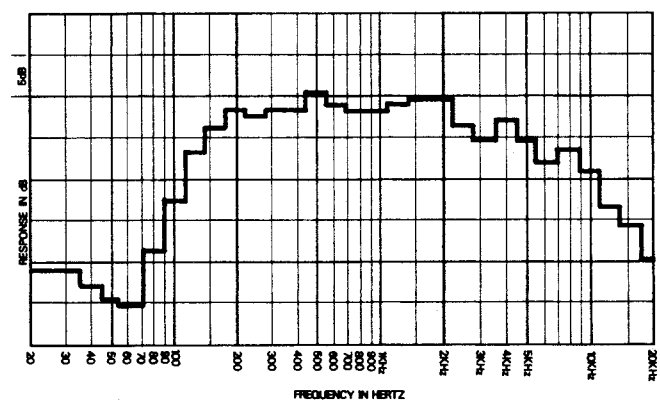

FIGURE 11 –
HR90 and Mid Bass Curve (HR90 Coverage Area)

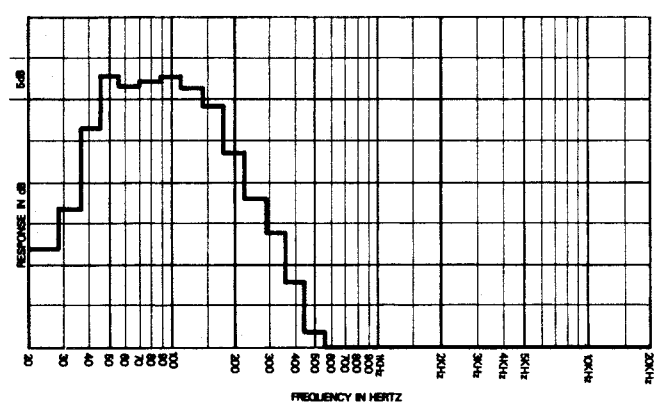

FIGURE 12 – Sub-woofer Curve (HR90 Coverage Area)

FIGURE 13 – HR90 Coverage Area (Final Adjustment)

Step 2

To set the level of the HR60 horn, the three microphones were moved to the HR60 coverage area. With the levels set as in Step 1, the level of the HR60 was increased until the frequency response curve matched the curve obtained in Step 1. Figure 14 shows the system response with the HR horn both on and off. No equalization settings were changed.

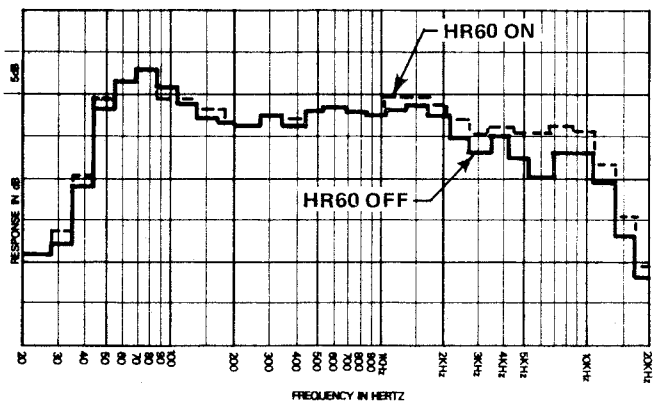

FIGURE 14 – HR60 Coverage Area Curves

Step 3

The final step was to incorporate the long-throw HR40 horn. This was done in the same fashion as the mid-throw horn. Figure 15 compares the response with the microphones in the beamwidth of the long-throw horn, with the level of the long-throw horn appropriately adjusted. As an experiment, the long-throw horn was turned on and off while spoken vocal material was played through the system. With the long-throw horn off, speech level was high, but the non-vowel speech components had a "muddy" quality.

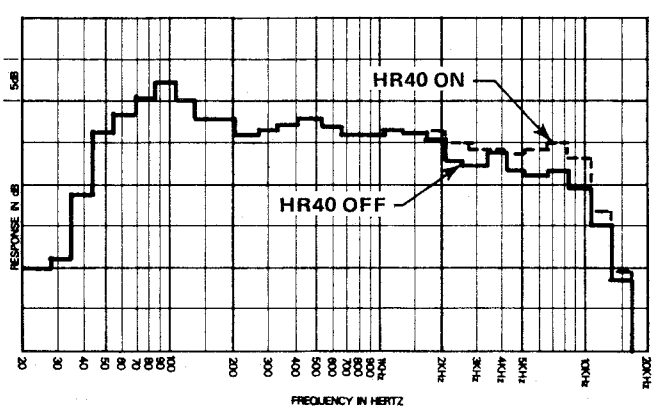

FIGURE 15 –
HR40 Coverage Area Curve (Horn On and Off)

Switching on the long-throw horn brought the sound clearly into focus, getting a quality strikingly similar to that observed from a position in the pattern of the short-throw horn.

Overall Coverage and Response Uniformity

Figure 16 shows an overlay of three frequency response measurements made with all system components operating but with the trio of measuring microphones in the three different locations: within the short-throw coverage pattern, within the mid-throw coverage pattern, and within the long-throw coverage pattern. Coverage is uniform within ± 2 dB over most of the frequency range.

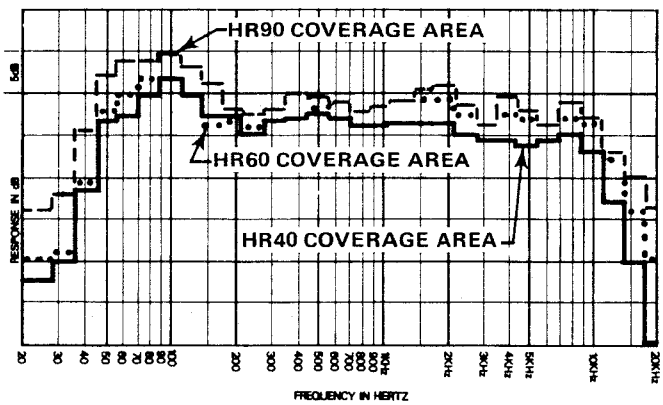

FIGURE 16 – Curves for Three Different Coverage Areas

Sound Pressure Levels

With wide range speech and music program, unweighted average levels of about 118 dB were obtained before the onset of significant amplifier clipping. This sound pressure level was judged sufficient for all Music Box activities, including rock and roll.

Any comments you wish to make about this addition or future additions of the PA Bible are welcome. Please send your response to:

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